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# Comparative Studies on the Quality and Safety of Commercially Available Dried Milk Powder

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Milk powder is an important dairy product worldwide. It is recognized for its ability to preserve nutrients and offers a long shelf life. It provides convenience in both storage and transportation. It plays a crucial role in multiple sectors of the food industry, such as the production of ice cream, yogurt, baked goods, and confections. This research evaluated the quality and safety of commercially available milk powders by conducting compositional and physicochemical analyses. The parameters examined included protein content, fat levels, solids-not-fat, total solids, pH, acidity, solubility index, bulk volume, bulk density, and flowability. A microbial analysis was performed, focusing on the total plate count (TPC). The analysis of the data indicated notable variations over time, including significantly reductions in pH, fat, protein, lactose, and solubility index, as well as significantly increases in acidity, moisture content, and wettability. These findings suggested that milk powder produced domestically had a reduced shelf life in comparison to international brands. The results highlighted the importance of implementing quality control measures to improve the longevity and market viability of milk powder products.
**Keywords**: Solubility index, quality, milk powder, flowability, microbial analysis, dairy products, shelf life, nutrients.

## INTRODUCTION

Milk has long been recognized as a vital food due to its nutritional value, especially for adolescents and children, as it provides essential nutrients like protein, fat, lactose, calcium, and various vitamins and minerals (Walmsley *et al.*, 2016). Dairy products make up a significant portion of the human diet, making the dairy industry one of the most important global agri-food sectors in terms of technological advancement, size, and economic importance (Wang *et al.*, 2019). Among dairy products, raw milk is often perceived as particularly healthy and is consumed for its potential health benefits, even by individuals with compromised immunity or specific dietary habits (Walmsley *et al.*, 2018). Milk, being a perishable food with unique properties, has a limited shelf life. To address this, milk is converted into powdered form, which increases its shelf life and preserves its quality. This conversion prevents spoilage and allows for long-term storage without the need for refrigeration, making it particularly useful for those lacking refrigeration facilities (Henao *et al.*, 2019). The composition of milk powder depends on the type of raw milk used, with sheep milk containing higher protein and fat content compared to buffalo milk (Yuan *et al.*, 2022). The average composition of milk powder includes 26-28.5% fat, 36-38.5% lactose, 24.5-27% protein, 2-4.5% moisture, and 5.5-6.5% ash (Li *et al.*, 2019). The structure of milk powder results from a Maillard reaction between proteins and lactose, which can be influenced by storage conditions like humidity and temperature (Xiao *et al.*, 2019). The flavor of milk powder is sweet and appetizing, with a light creamy appearance. Milk powder serves various culinary and industrial purposes, being used in confectionery, bakery products, dry sauces, soups, and ice cream (Finnegan *et al.*, 2017). There are different types of milk powders available, including instant and skim milk powder, which cater to diverse needs such as quick dissolution or low-fat content for baby foods and desserts (Wong *et al.*, 2017). Commercial drying methods like drum and spray drying are used to produce milk powder by vaporizing and removing moisture as steam. Factors influencing shelf life include moisture content, oxygen exposure, packaging, light exposure, and storage temperature (Wu *et al.*, 2008). Agglomeration techniques, such as single-pass and rewet methods, enhance the dispersibility and solubility of milk powder, with lecithin added as a wetting agent to further improve these properties (Li *et al.*, 2019). Optimal storage conditions for milk powder include reduced oxygen content, moderate heat treatment, and a storage temperature of about 20°C or lower (Yuan *et al.*,

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2022). Shelf life can also be extended through the use of antioxidants and cool, dry storage conditions (Li *et al.,* 2019). The quality of milk powder is influenced by its microbial content, which is determined by the initial microbial load of raw milk and the effectiveness of pasteurization and drying processes (Akhtar *et al.,* 2003). Heat-resistant enzymes in some microbial species can affect the sensory properties and functionality of milk powder, impacting its shelf life (Li *et al.,* 2019). Microbial quality is assessed through chemical and microbiological analysis of dried milk powder and its reconstituted form (Li *et al.,* 2019). The physicochemical stability of milk powder during storage depends on factors like lactose crystallization, lipid oxidation, and Maillard reactions, which can lead to quality changes such as browning and caking (Li *et al.,* 2019). Processing parameters play a significant role in determining the sensory and functional properties of milk powder. These parameters influence drying conditions, lipid oxidation kinetics, and reactions affecting flavor and texture (Andersson *et al.,* 2007). Milk powder's ability to retain moisture and act as an emulsifier and plasticizer is particularly valued in the baking industry, where it enhances the tenderness and texture of products like cookies and cakes (Li *et al.,* 2019). Overall, milk powder offers advantages in terms of storage, cost-effectiveness, and diverse applications, making it a crucial component in various food industries.

- To evaluate the physiochemical quality of different milk powder brands produced by different dairy industries of Pakistan.
- To access the microbial, safety and shelf life of different milk powders present in local market of Pakistan.

## MATERIALS AND METHODS

***Collection of samples*:** Different samples of dried milk powder were procured from the local market of Faisalabad.

**Physical and chemical analysis of powdered milk**

***pH*:** Digital pH meter was used to measure ph. Thirteen grammes of material dissolved in 100mL distilled water. Adjusted to 20°C, pH meter electrodes were immersed and recorded. Normalizing the equipment with a pH 4.0–7.0 buffer solution, the reading was easily recorded.

***Acidity Procedure*:** 13g powdered milk was diffused in 100 mL purified water in a beaker. Reconstituted powdered milk (17.6 mL) was pipetted into a 250 mL Erlenmeyer flask. Two to three drops of phenolphthalein were added by the indicator. After that, N/10 NAOH was titrated until pink tone remained for 30 seconds. The following phrase calculated acidity according to AOAC (2019).

$$\text{Acidity }\% = \frac{Volume\ of\ 0.1N\ NAOH\ uaed\ (mL) \times 0.09}{mL\ of\ sample\ (g)} \times 100$$

***Moisture determination*:** The typical oven drying method estimated dried milk powder moisture. To determine moisture content, 5.0 g of each sample was dried in a hot air oven at 105°C until the constant weight was reached, per AOAC (2019). The following expression determined dried milk powder moisture:

$$\text{Moisture }\% = \frac{orginal\ weight\ of\ sample - weight\ of\ dried\ sample}{original\ weight\ of\ sample} \text{x}100$$

***Ash*:** A 3g crucible sample was obtained. The sample was weighed and heated until smokeless. The procedure is charring. The crucible was heated overnight to 525°C in the furnace after charring. Removed crucible, placed in desiccator, and weighed again.

$$\text{Ash} = \frac{weight\ of\ ash}{weight\ of\ sample} \text{x}100$$

***Fat*:** Sulfuric acid was always 10 mL in the butyrometer. After 2.5g of milk powder was placed in a 35% butyrometer, 1mL of isoamyl liquor and water were added to accurately measure fat. Then stoppered and flipped the butyrometer several times to process and blend all milk contents. After centrifuging the butyrometer for 10 minutes, the fat was taken from the scale. All determinations were repeated to get mean value.

***Protein*:** Sample crude protein was measured using AOAC (2016)'s kjeldahl technique. Formula for crude protein percentage. 2 g powdered milk was added to the assimilation flask. The flask received 40 mL of and 40 mL of refined water with a digesting tablet. Warming produced a clear or light green color. Total processing time was 35 hours. After marking the sample for distillation, the processed sample was placed in a 250 mL volumetric flask and 10 mL of 40% NaOH was added to a micro kjeldahl apparatus. A beaker with 12 drops of methyl red indicator received 10 mL of 4% boric acid. Steam produced NH3 gas fume, which boric acid trapped. Distillation lasted 2 minutes when the color turned golden. A solution of boric acid which contained $NH_3$ and it was titrated with 0.1N $H_2SO_4$. The amount from 0.1N $H_2SO_4$ to the presence of red tone was recorded.

$$\%\text{N} = \frac{Vol.of\ 0.1N\ \text{H}_2\text{SO}_4 \times\ Vol.of\ dilution \times 0.0014}{Wt.of\ sample\ \times \text{Vol. of diluted sample taken}} \times 100$$

Crude Protein %=N% $\times$ 6.38

***Bulk volume of powder*:** Filled a glass chamber with 100 g of sample and tap volumeter stamp. The effects of bulk of the powder were estimated as loose repeatedly tapped. Powder 100 g was weighed and placed in the measuring cylinder. Avoiding cylinder shaking or tapping. The powder was levelled with a spatula. Loose powder bulk volume was V1. Volumeter stamp tapped cylinder 100 times. V2 was tapped powder bulk volume. Cylinder tapping continued 1250 times. Tapped to excessive bulk volume was V3.

Bulk volume = volume/weight (mL/100g)

***Wettability*:** Weighing 13 g of powder in 40 °C distilled water. The beaker received 100 mL of deionized water at the right temperature. On top of the beaker was the funnel. The pestle was then placed in the funnel. Powder surrounded the pestle. Lifting the pestle started the stopwatch. Watch stopped until all powder was wetted.

***Flowability*:** The time in seconds needed for a certain volume of powder to leave a spinning drum through a slit of a specific size is called flowability. The drum was filled with powder and lidded. Drum revolution and stopwatch started. The watch stopped and recorded the time when all the powder left the drum.

***Solubility index*:** The dried milk powder solubility index was determined using IDF (2014). In the 500 mL beaker, 13 g of sample was weighed and placed in 100 mL of 24°C distilled water. After 15 minutes, the contents were combined. The tube was filled with marked 15 mL powdered milk and centrifuged at 900 rpm for 5 minutes. The tube was removed after the first centrifugation to remove the sediment-free liquid, which may exceed 5 ml. The sediment layer was covered and the tube filled with distilled water to the visible point. Wires spread precipitate in the tube. After centrifuging the tube for a few minutes, the residue was measured in milliliters.

***Bulk density*:** The cylinder was weighed without top. Filling cylinder with milk powder rim. Avoiding cylinder shaking or tapping. Top removed, powder rejected to chamber edge. Protect the cylinder from compression and vibration. A lot of powder from the chamber's edge was brushed off. Weighting the cylinder (W1) showed the loose bulk density of powder. The second stage repeated and the cylinder tapped 100 times in volumeter stamp. The third stage was repeated and weighed (W2). Tapped powder bulk density indicated weight. Step two was performed 1250 times in the volumeter stamp. Third step repeated and weighed (W3). Extreme bulk density was suggested by this weight.

The results were expressed as:

- Loose powder bulk density tapped 0 times
- Tapped bulk density tapped to 100 times
- Tapped to extreme bulk density tapped to 1250 times

Bulk density = Wx/100

Wx = weight of powder in grams; 100 = volume of cylinder in $cm^3$; Insolubility index = mL sediment

***Lactose*:** The lactose content was measured using AOAC (2016). 25 g milk powder was diluted in 25 mL distilled water, clarified with 2 mL lead acetate and 3 mL potassium oxalate, and filtered to 250 mL. After then, the 300 mL Erlenmeyer flask contained 25 mL Fehling solution. A 15 mL sugar solution was added or asbestos-covered cloth was used. 1 mL sugar solution was boiled for 10–15 seconds till the color faded. About 3.5 drops of methylene blue indicator were added. After the indication color entirely decolorized, boiling stopped. The lactose table estimated lactose.

***Determination of total solids*:** AOAC (2016) was used to calculate total solids. A clean, dry aluminum pan held 5.0 g of sample. Before adding the sample, empty dish weight was taken and the sample weight was taken. The tray was cooked in a steam bath for 10–15 minutes and placed in a 75°C hot air oven for 12 hours. After cooling in a desiccator, the dish was weighed. Cooling, warming, or weighing were repeated until the difference was under 0.5 mg. Contents of total solids had been estimated as the following expression:

Total solid (%) = $W1/W_o \times 100$

***Determination of solid not fat*:** SNF were found by the method described by (Pereira *et al.*, 2018) It was calculated by using the following formula:

SNF%= TS (%) - Fat (%)

## MICROBIAL ANALYSIS

***Total plate count method*:** With the following method we can prepare solution:

- Mix 13.80g nutrient agar with distilled water to make a volume of 600mL
- Mix 3.75g of peptone with distilled water for a total volume of a 600mL
- Mix 3.56g of NACL with distilled water to make saline solution of 250mL

***Preparation of petri plates*:** Primarily the nutrient agar was autoclaved the solution at 121°C for 15 min. Then it was placed in water bath so that the temperature was reduced. Then the nutrient agar was poured in solution in the petri plates and it was left at room temperature for solidification.

***Serial dilution*:** About 9mL of saline solution was poured in test tubes and it was marked 1,2,3 with the help of micropipette and it was autoclaved at 121°C for 15 min. About 2mL sample was mixed with 15mL of peptone water and was put in the stomacher. 1mL sample was taken from the stomacher bag and it was added in test tube 1. Transferred 1mL from it to test tube 2 and then to test tube 3 with the help of micropipette.

***Pouring and spreading*:** About 0.1mL of sample from each test tube was taken and poured in respective labeled petri plates. The sample was spread with the help of a sterilized glass spreader.

***Incubation*:** The petri plates were placed in the incubator at 45°C for 24-48 hours to get bacterial growth. TPC was measured using a colony counter and expressed as cfu/mL or cgu/g.

***Sensory Evaluation*:** Powdered milk sample tests were assessed organoleptically for color and taste by a panel of 6 skilled judges utilizing a 9-point hedonic scale by following the methodology of Akeem *et al.* (2018).

***Statistical Analysis*:** Data obtained under statistical analysis using completely random design (CRD) and ANOVA methods.

## RESULTS AND DISCUSSION

***pH*:** Milk powder has a pH of 6.7–6.9. Because it has lactic acid. The acid- or alkaline-forming state is more relevant than the pH level (Hillman *et al.*, 2019). Acid provides pH, the negative logarithm of $H^+$ ions (Zhu *et al.*, 2019). Table 1 shows mean pH values for milk powders. Zero-day

International Product 1 pH ranged from 6.60 to 6.58, decreasing by 90 days. National Product 2 pH was highest at 0 and 30 days and declined at 60 and 90 days. International Product 2 had a pH of 6.71 at zero and 30 days, but it dropped after 60 and 90 days.

Milk Fresh Powdered Milk had a pH of 6.75 at zero and 30 days, however it dropped at 60 and 90 days. National Product 1 Milk Powder had a pH of 6.86 at zero and 30 days, however, it dropped at 60 and 90 days. In Table 2, the analysis of variance for pH of different milk powders at different time intervals showed extremely significant findings. The growth of psychrophilic and thermophilic bacteria may lower the pH of all milk powder samples. Similar results were reported by Mazivila *et al.* (2020). Milk powder samples were held at ambient temperature for 30, 60, and 90 days with 4.49 percent moisture-decreased pH after 90 days. Significant pH changes decreased calcium content and specific surface area and increased viscosity, water binding, oil binding, emulsifying, foaming, and buffering (Elias *et al.*, 2008). Two months of storage at 25 ± 1 °C resulted in a 27.78% drop in solubility for control powder compared to treated powder Changing pH may cause these changes. To minimize particle mass, milk powder dispersions were alkalized to pH 10.0 or 11.0 (Rogers *et al.*, 2012).

**Table 1. Comparison for pH of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 6.61±0.06[l] | 6.61±0.02[h] | 6.60±0.05[k] | 6.58±0.05[f] |
| International Product 2 | 6.71±0.06[j] | 6.71±0.11[i] | 6.60±0.05[f] | 6.59±0.05[d] |
| Milk fresh | 6.75±0.16[h] | 6.75±0.01[h] | 6.79±0.01[d] | 6.87±0.01[c] |
| National Product 1 | 6.86±0.05[g] | 6.86±0.07[f] | 6.80±0.02[c] | 6.80±0.01[b] |
| National Product 2 | 6.87±0.11[b] | 6.87±0.06[b] | 6.81±0.04[d] | 6.85±0.06[a] |

Effect of storage time on pH was highly significant (means carrying the same letter in row and column are statistically non-significant)

**Table 2. Analysis of variance of comparison for pH of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 3.0112 | 0.7528 | 34.21** |
| Storage days | 4 | 2.0126 | 0.5031 | 22.86** |
| Samples*days | 16 | 4.0123 | 0.2507 | 11.39** |
| Error | 20 | 1.0110 | 0.0220 | |
| Total | 44 | | | |

**= Highly Significant

***Acidity***: By titrating a known volume of reconstituted milk with 0.1N NaOH and phenolphthalein, lactic acidity is measured in %. The titratable acidity of dried milk powder is the number of milliliters of 0,1 mol/sodium hydroxide solution needed to neutralize 10 g of solids-not-fat reconstituted milk in the presence of phenolphthalein until it turns pink.

Acridity measures lactic acid in dairy products and powders. The main reasons for fermentation are to improve flavor and prevent microbial growth (Zouari *et al.*, 2020). Table 3 shows milk powder acidity. Acidity varied from 0.145 to 0.168 for milk powder samples and time analysis. National Product 1 Milk Powder had the lowest acidity at 0 and 30 days, 0.145, and increased at 60 and 90 days. National Product 2 Milk Powder had the greatest acidity at 0.157 at 30 days and 0.156 at 0, 60, and 90 days. The analysis of variance for the acidity of milk powder samples was highly significant in Table 4. Heating time, temperature, and storage temperature can affect acidity. All samples and four-time analyses showed increasing acidity during storage (Yeh *et al.*, 2013). This may cause lactose-to-lactic acid bacteria to multiply. Milk powder storage quality is affected by acidity (Jimenez *et al.*, 2008). Similar outcomes were found by Martínez-Padilla et al (2014). They found that acidity and moisture content rose with decreasing total dry matter and acid degree value during milk powder storage.

**Table 4. Analysis of variance of comparison for acidity of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 2.267 | 0.5660 | 8.89** |
| Storage days | 4 | 2.667 | 0.6660 | 10.47** |
| Samples*days | 16 | 4.993 | 0.3120 | 4.90[NS] |
| Error | 25 | 1.590 | 0.0636 | |
| Total | 49 | | | |

**= Highly Significant; NS= Non Significant

***Moisture***: Water content characteristics determine dairy powder storage quality and stability. Higher water content milk powder causes stickiness, although lactose crystallization can immerse or liberate moisture from

**Table 3. Comparison for acidity of commercially available dried milk powder.**

| Sample | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 0.151±0.01[m] | 0.152±0.01[m] | 0.154±0.05[k] | 0.166±0.16[i] |
| International Product 2 | 0.155±0.04[l] | 0.159±0.02[i] | 0.164±0.02[ki] | 0.168±0.13[g] |
| Milk fresh | 0.149±0.01[j] | 0.149±0.04[f] | 0.155±0.01[c] | 0.161±0.08[e] |
| National Product 1 | 0.145±0.03[h] | 0.149±0.03[e] | 0.155±0.03[ac] | 0.159±0.02[ab] |
| National Product 2 | 0.156±0.02 [ca] | 0.157±0.10 [ca] | 0.156±0.12[cb] | 0.156±0.05[abc] |

Effect of storage time on acidity was highly significant (Means carrying the same letter in row and column are statistically non-significant)

**Table 5. Comparison for moisture of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 3.67±0.01$^{a}$ | 3.68±0.05$^{ab}$ | 3.69±0.34$^{d}$ | 3.69±0.03$^{da}$ |
| International Product 2 | 3.74±0.06$^{b}$ | 3.75±0.02$^{ac}$ | 3.77±0.03$^{dg}$ | 3.78±0.02$^{f}$ |
| Milk fresh | 3.79±0.05$^{b}$ | 3.80±0.03$^{bc}$ | 3.82±0.06$^{abc}$ | 3.83±0.02$^{ba}$ |
| National Product 1 | 3.83±0.01$^{cd}$ | 3.84±0.02$^{cdf}$ | 3.84±0.05$^{cf}$ | 3.86±0.01$^{cfg}$ |
| National Product 2 | 3.68±0.01$^{abc}$ | 3.69±0.03$^{bc}$ | 3.70±0.01$^{ba}$ | 3.71±0.02$^{ab}$ |

Effect of storage time on moisture was highly significant (Means carrying the same letter in row and column are statistically non-significant)

amorphous material, improving non-enzymatic deterioration (Qin *et al.*, 2017).

Spray drying is used to dry dairy powders, which have an average moisture content of 3-4%. Atomizing the feed, spray-air contact, drying, and product separation from drying air are the basic steps of spray drying (Garacia *et al.*, 2007).

Too much moisture causes caking and flowability concerns. To preserve powdered milk water content, drying air thermodynamics must be controlled (Zouari *et al.*, 2019).

Milk powder is hygroscopic and polyethene is permeable, which may increase moisture during storage. Table 5 shows that National Product 1 Milk Powder had the highest moisture content at 0day, 3.83. Analysis at 90 days showed a 3.86 rise. National Product 2 mean 0day value was 3.69, the lowest of all samples. The 90-day analysis showed a 3.71 rise.

Mean International Product 1 was 3.67 at 0-day analysis; International Product 2 was 3.74 and grew to 3.78 during 90-day analysis. Milk Fresh's moisture content rose from 3.79 to 3.83. Results were extremely significant according to statistical analysis.

**Table 6. Analysis of variance of comparison for moisture of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 1.0596 | 0.2649 | 88.3** |
| Storage days | 4 | 1.0080 | 0.252 | 84.0** |
| Samples*days | 16 | 2.6000 | 0.1625 | 54.17** |
| Error | 30 | 0.1100 | 0.0030 | |
| Total | 54 | | | |

**= Highly Significant

Milk powder absorbs moisture from its surroundings at ambient temperatures, making moisture monitoring and measurement crucial. In dairy powder applications, moisture is usually assessed after spray drying or before packaging (Grigioni *et al.*, 2007).

Milk powders absorb ambient moisture, which affects their storage properties. Preventing air moisture absorption is crucial to preserving its initial colloidal structure, preventing stale taste and odor, and darkening the color (Kelly *et al.*, 2007).

***Ash*:** Ash content defines inorganic materials in every product. Dairy ash is rich in minerals and nutrients and low in calories. Powdered milk has 6% ash (Chen *et al.*, 2018).

In diverse samples of milk powder, National Product 1 Milk Powder had the lowest ash content in 60 days at 5.710 and National Product 2 Milk Powder had the highest in 0 days at 5.790. Table 7 shows that National Product 2 Milk Powder had the highest mean ash level at 0day, 5.790, and declined at 30, 60, and 90 days. The mean ash of fresh milk powder was 5.770 at 0 days and rose at 30, 60, and days. International Product 1 had around 5.760 ash at 0 and days. It reduced at 60 days and climbed at 90 days. International Product 2 had 5.740 ash at 0 and 30 days, reduced at 60 days, and increased at 90 days. Table 8 indicated that milk powder sample ash analysis of variance results was extremely significant. Ash content may have decreased slightly due to moisture absorption during long storage. Polyethylene's moisture permeability may potentially be a factor (Mirosa *et al.*, 2020).

**Table 8. Analysis of variance of comparison for ash of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 3.040 | 0.7600 | 13.81** |
| Storage days | 4 | 3.330 | 0.8325 | 15.13** |
| Samples*days | 16 | 5.373 | 0.3350 | 6.90* |
| Error | 22 | 1.212 | 0.0550 | |

**Table 7. Comparison for ash of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 5.76±0.06$^{a}$ | 5.76±0.06$^{ae}$ | 5.75±0.06$^{ab}$ | 5.76±0.05$^{abc}$ |
| International Product 2 | 5.74±0.05$^{ba}$ | 5.74±0.05$^{ba}$ | 5.73±0.06 $^{bd}$ | 5.73±0.01$^{ij}$ |
| Milk fresh | 5.77±0.02$^{f}$ | 5.78±0.01$^{ab}$ | 5.77±0.05$^{abc}$ | 5.77±0.06$^{bc}$ |
| National Product 1 | 5.72±0.02$^{j}$ | 5.72±0.02$^{i}$ | 5.71±0.05$^{ca}$ | 5.71±0.03$^{cd}$ |
| National Product 2 | 5.79±0.02$^{ml}$ | 5.78±0.01$^{cad}$ | 5.780±0.21$^{ca}$ | 5.78±0.01$^{ca}$ |

The effect of storage time on ash was highly significant (Means carrying the same letter in row and column are statistically non-significant)

**Table 9. Comparison for fat of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 27.60±0.02$^{f}$ | 27.60±0.02$^{h}$ | 27.58±0.11$^{l}$ | 27.58±0.01$^{m}$ |
| International Product 2 | 26.68±0.02$^{fj}$ | 26.68±0.12$^{hl}$ | 26.66±0.11$^{bc}$ | 26.64±0.02$^{ca}$ |
| Milk fresh | 24.66±0.02$^{i}$ | 24.64±0.02$^{km}$ | 24.64±0.02$^{n}$ | 24.61±0.02$^{p}$ |
| National Product 1 | 25.74±0.05$^{bc}$ | 25.74±0.05$^{ba}$ | 25.71±0.03$^{d}$ | 25.71±0.03$^{df}$ |
| National Product 2 | 26.62±0.01$^{i}$ | 26.60±0.02$^{k}$ | 26.60±0.02$^{m}$ | 26.58±0.02$^{n}$ |

The effect of storage time on fat was highly significant (Means carrying the same letter in row and column are statistically non-significant)

| | |
|---|---|
| Total | 46 |

**= Highly Significant; *= Significant

***Fat*****:** Fat enhances flavor, appearance, consistency, and mouthfeel (Keogh *et al.*, 2004). Fat gives the product energy and calories (Zhang *et al.*, 2020).

Table 9 shows that International Product 1's mean fat value was 27.60 at 0 and 60 days and dropped at 60 and 90 days. Milk Fresh milk powder had the lowest fat percentage in all tests at 24.66 at 0 day, 24.64 at 30, 60, and 90 days. International Product 2 mean was 26.68 at 0 and 30 days, but it fell after 60 and 90 days. National Product 1 Milk Powder had 25.74 grammes of fat at 0 and 30 days, but less at 60 and 90 days. National Product 2 Milk Powder had 26.62 grammes of fat at 0 day and reduced after 30, 60, and 90 days. Table 10 indicated significantly significant fat analysis of variance results for milk powder samples. Hydrolysis and oxidation of dry milk powder fat may cause fat alterations (Tumwine *et al.*, 2019). Milk fat structure may vary based on the cow's grazing routine and diet fat content (Rasouli-Pirouzian *et al.*, 2017). Unsaturated fats create C18 unsaturated fats, which weaken milk fat. The 29% milk powder was 98% fat and 2% lactose, an inactive protein (Feng *et al.*, 2021). Microbial thermostable lipases in fat content are one of the biggest shelf life deteriorations of milk powder (Khan *et al.*, 2021).

**Table 10. Analysis of variance of comparison for fat of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 3.7981 | 0.9495 | 110.4** |
| Storage days | 4 | 2.0017 | 0.5004 | 58.18** |
| Samples*days | 16 | 4.7998 | 0.2999 | 34.87** |
| Error | 25 | 0.215 | 0.0086 | |
| Total | 34 | | | |

*= Highly Significant

***Protein*****:** Ultrafiltration/diafiltration precedes evaporation and drying in high-protein milk powder production. Milk components interact throughout these processes, affecting powder functioning. Dried milk powder is high in protein. Protein gives finished products flavor and consistency. Protein is also a source of calories (Bastıoğlu *et al.*, 2016). The solubility index varies with protein concentration. At high temperatures, intensity can denature protein (Moore *et al.*, 2010). Under milk circumstances, casein micelles' structure and stability are well established (Elik *et al.*, 2020). Table 11 indicates that National Product 1 had the largest protein level at 0 days, decreasing at 30, 60, and 90 days. International Product 2's protein level was 25.60 at 0 days and dropped at 30, 60, and 90 days. International Product 1 had 25.18 grammes of protein at 0 and 30 days, but less at 60 and 90 days. Milk fresh protein content was 26.20 at 0 and 30 days and dropped at 60 and 90 days. National Product 2 protein content was 26.10 at 0 and 30 days and dropped after 60 and 90 days. Table 12 indicated substantial protein analysis of variance values for milk powder samples. Thermal deterioration may change milk powder protein content, according to Strani *et al.* (2021). Protein breakdown during lengthy and poor storage may cause the decline (Nascimento *et al.*, 2019).

**Table 12. Analysis of variance of comparison for protein of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 3.8532 | 0.5500 | 8.16** |
| Storage days | 4 | 3.2933 | 0.8233 | 12.21** |
| Samples*days | 16 | 6.8826 | 0.4301 | 6.38* |
| Error | 15 | 1.0120 | 0.0674 | |
| Total | 39 | | | |

**Table 11. Comparison for protein of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 25.18±0.01$^{a}$ | 25.18±0.01$^{ab}$ | 25.16±0.13$^{d}$ | 25.15±0.12$^{g}$ |
| International Product 2 | 25.26±0.02$^{bc}$ | 25.24±0.01$^{cd}$ | 25.21±0.01$^{ef}$ | 25.18±0.01$^{gh}$ |
| Milk fresh | 26.20±0.01$^{ab}$ | 26.20±0.01$^{b}$ | 26.18±0.14$^{bc}$ | 26.10±0.01$^{b}$ |
| National Product 1 | 26.34±0.01$^{ca}$ | 26.30±0.01$^{cd}$ | 26.30±0.21$^{cf}$ | 26.25±0.01$^{h}$ |
| National Product 2 | 26.10±0.02$^{e}$ | 26.10±0.12e | 26.8±0.13$^{ef}$ | 26.5±0.02$^{f}$ |

The effect of storage time on the protein was highly significant (Means carrying the same letter in row and column are statistically non-significant)

**Table 13. Comparison for lactose of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 35.68±0.04[a] | 35.64±0.01[ac] | 35.60±0.01[ab] | 35.60±0.01[abc] |
| International Product 2 | 34.81±0.45[ab] | 34.77±0.01[cd] | 34.72±0.01[cdf] | 34.76±0.03[efg] |
| Milk fresh | 35.88±0.65[b] | 35.82±0.08[bc] | 35.75±0.02[ba] | 35.81±0.02[b] |
| National Product 1 | 35.62±0.05[ba] | 35.56±0.03[ba] | 35.51±0.01[bc] | 35.56±0.03[bc] |
| National Product 2 | 36.76±0.05[cd] | 36.72±0.01[ca] | 36.65±0.02[bc] | 36.71±0.01[cf] |

Effect of storage time on lactose was highly significant (Means carrying the same letter in row and column are statistically non-significant)

**= Highly Significant; *= Significant

According to Xiao *et al.* (2019), the interaction of whey proteins with casein micelles, particularly κ-casein, affects their behavior during processing. Some casein micelles aggregate and whey proteins bind to them during evaporation, increasing their size.

***Lactose*:** Only milk contains lactose. The enzyme lactose hydrolyses it to glucose and galactose for absorption and use (Kim *et al.*, 2002). Lactose constitutes 38% of milk powder solids. The Maillard reaction, a non-enzymatic sugar degrading reaction, is especially apparent in dairy products (Vaclavik *et al.*, 2010). Due to their high lactose and lysine content, milk powders are especially vulnerable to Maillard reaction (Torres *et al.*, 2017). Reducing carbohydrates react with protein side chains, especially lysine, during heating and storage of milk products, forming amino acid sugar reaction products (Zhang *et al.*, 2020). Table 13 shows that lactose concentration in milk powder samples ranged from 36.76 to 34.71. National Product 2 Milk Powder had 36.76 lactose at 0 days and declined at 30, 60, and 90 days. International Product 2 had the lowest lactose level at 34.81 at 0 days and declined at 30, 60, and 90 days.

Lactose changes due to lactic acid generation. The rate of lactose and lysine breakdown depends on temperature Cavapozzi *et al*. (2020).

Table 14 indicated substantial lactose analysis of variance values for milk powder samples. Lactose can cause powder stickiness, fouling during drying, and caking and related issues during storage (Lyu *et al.*, 2012). Lactose, a reducing carbohydrate, can engage in the Maillard reaction with free amino groups of proteins, peptides, and free AA, according to Deshwal *et al*. (2020). Baldwin *et al*. (2020) suggested that milk powder stickiness and caking may be caused by lactose composition changes.

**Table 14. Analysis of variance of comparison for lactose of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 2.153 | 0.5382 | 538.2*** |
| Storage days | 4 | 2.970 | 0.7425 | 742.5*** |
| Samples*days | 16 | 6.560 | 0.4100 | 410.0*** |
| Error | 12 | 0.012 | 0.0010 | |
| Total | 36 | | | |

***= Highly Significant

***Solubility index*:** Solubility index is sediment volume in milliliters after centrifugation. This approach works for skimmed milk, whole milk, and sweet buttermilk powder, but other soluble and dried dairy products can be employed (Khan *et al.*, 2021).

The optimal solubility index for full cream dry milk was 1.25 ± 0.11mL, half cream was 1.2 ± 0.11mL, and skimmed milk powder was 1.5 ± 0.12mL when reconstituted with tap water. In table 15, mean values of four milk powder samples showed that Milk Fresh's solubility index was greater at 0 day and declined at 30, 60, and 90 days. National Product 1's solubility index was 0.80 at 0 day and dropped at 30, 60, and 90 days, the lowest of all samples. Milk solids lose solubility quickly at 15–38% moisture.

As milk solids contact water longer, this unstable range expands. Only milk powders with bulk densities below 0.4 g/mL have maximum self-dispersion solubility. Processing and storage time affect solubility index, according to Reddy *et al*. (2014).

Vaclavik *et al.* (2010) found that preheat holding time increased milk powder solubility. Maillard process decreases solubility during storage. Hygroscopic milk powders absorb water from humid environments. Milk powders can become

**Table 15. Comparison for solubility index of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 0.94±0.06[ab] | 0.94±0.06[ab] | 0.92±0.01[ab] | 0.92±0.01[ab] |
| International Product 2 | 0.87±0.01[bc] | 0.86±0.02[bc] | 0.86±0.02[ba] | 0.84±0.01[ba] |
| Milk fresh | 0.97±0.01[a] | 0.96±0.02[a] | 0.91±0.01[a] | 0.93±0.02[a] |
| National Product 1 | 0.80±0.05[bc] | 0.80±0.05[bc] | 0.78±0.01[bc] | 0.79±0.11[bc] |
| National Product 2 | 0.82±0.01[b] | 0.80±0.03[b] | 0.75±0.01[b] | 0.75±0.01[b] |

The effect of storage time on the solubility index was significant (Means carrying the same letter in row and column are statistically non-significant)

sticky, caked, or lumpy and lose flowability and solubility when moisture levels are high (Saha *et al.*, 2019). Table no.16 indicated that the results were significant.

**Table 16. Analysis of variance of comparison for solubility index of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 1.234 | 0.3085 | 6.393* |
| Storage days | 4 | 4.193 | 1.0482 | 7.822* |
| Samples*days | 16 | 1.866 | 0.1166 | 0.87$^{NS}$ |
| Error | 15 | 2.014 | 0.134 | |
| Total | 34 | | | |

***=** Significant; NS= Non Significant

***Wettability*****:** Wetting is the first step in rehydrating a powder, followed by swelling, sinking, dispersion, and dissolution. Powder wettability is the time it takes to completely wet a specific amount of powder in water at a specified temperature (Deshwal *et al.*, 2020). Wettability testing checked powdered milk dispersal. Storage conditions increased or decreased powdered milk scattering (Patil *et al.*, 2016). Table 17 illustrates the wettability of all the samples. International Product 1 had 200 at 0-day analysis and rose at 30, 60, and 90 days, which was the highest. At 0, National Product 2 wettability was 164; at 30, 60, and 90 days, it increased. Table 18 shows extremely significant results.

Wettability is the time (in seconds) it takes a powder to permeate water's still surface. Powder absorbs water on the surface and gets wet (Bilge *et al.*, 2016). Surface activity, surface area, surface charge, particle size, density, porosity, and moisture-absorbing compounds affect powder particle wettability. Wetting powder particles is generally the rate-controlling step, according to Bizzi *et al.* (2017). Wettability increased with particle size in medium-, low-, and high-heat milk powders regardless of sample size (Bilge *et al.*, 2016).

***Flowability determination*****:** Cohesion and compressibility directly affect powder flowability. Handling and processing milk powders requires consistent flow from hoppers and silos (Deshwal *et al.*, 2020). Powder flow, often called flowability, is the movement of a bulk of particles in relation to neighboring particles or the container wall. Powder flowability is the ability of a powder to flow in a certain piece of equipment. All sample flowability is shown in the table below. Table 19 shows that International Product 2 had the highest flowability of all samples, 0.60 at 0 day and increasing at 30, 60, and 90 days. Milk fresh flowability was lowest at 0.51 at 0 day. International Product 1 had a mean value of 0.520, International Product 2 0.640, Milk fresh, National Product 1, and National Product 2 0.47, 0.56, and 0.61. Table 20 indicates noteworthy outcomes. Powder flowability depends on both the material's physical qualities and the handling system's processing conditions (Deshwal *et al.*, 2020). Hygroscopic milk powders absorb water from humid environments. Milk powders can become sticky, caked, or lumpy and lose flowability and solubility when moisture levels are high (Cao *et al.*, 2013). This study used shear cell techniques to measure and compare the flow properties of commercial skim-milk powder (SMP), whole milk powder (WMP), and 73% high fat milk powder (HFP) and examine how storage temperature and air moisture affected these powders (Cao *et al.*, 2013).

**Table 18. Analysis of variance of comparison for wettability of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 2.798 | 0.6995 | 18.70** |
| Storage days | 4 | 2.012 | 0.5030 | 13.44** |
| Samples*days | 16 | 4.108 | 0.2560 | 6.84* |
| Error | 30 | 1.123 | 0.0374 | |
| Total | 44 | | | |

**= Highly Significant; ***=** Significant

**Table 20. Analysis of variance of comparison for flowability of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 2.181 | 0.5452 | 6.34* |
| Storage days | 4 | 2.834 | 0.7085 | 8.24* |
| Samples*days | 16 | 8.781 | 0.5488 | 6.38* |
| Error | 35 | 3.041 | 0.0860 | |
| Total | 47 | | | |

*=Significant

**Table 17. Comparison for wettability of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 200±2.00$^{ac}$ | 202±2.01$^{re}$ | 204±2.02$^{a}$ | 202±2.00$^{a}$ |
| International Product 2 | 170±2.39$^{bv}$ | 174±3.31$^{qe}$ | 170±2.39$^{er}$ | 171±2.91$^{b}$ |
| Milk fresh | 186±3.05$^{ba}$ | 190±3.01$^{abc}$ | 184±3.05$^{bc}$ | 186±3.51$^{b}$ |
| National Product 1 | 190±3.01$^{pr}$ | 194±3.05$^{st}$ | 196±3.12$^{tu}$ | 193±3.12$^{r}$ |
| National Product 2 | 164±2.01$^{cd}$ | 166±2.01$^{ca}$ | 168±2.01$^{c}$ | 166±2.01$^{c}$ |

The effect of storage time on wettability was highly significant (Means carrying the same letter in row and column are statistically non-significant)

**Table 19. Comparison for flowability of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 0.54±0.02$^{m}$ | 0.52±0.01$^{mn}$ | 0.51±0.01$^{mno}$ | 0.52±0.01$^{p}$ |
| International Product 2 | 0.62±0.49$^{r}$ | 0.64±0.41$^{rs}$ | 0.66±0.40$^{t}$ | 0.64±0.41$^{ab}$ |
| Milk fresh | 0.51±0.02$^{a}$ | 0.42±0.01$^{ba}$ | 0.51±0.02$^{a}$ | 0.47±0.01$^{ba}$ |
| National Product 1 | 0.58±0.05$^{b}$ | 0.54±0.02$^{ba}$ | 0.56±0.05$^{abs}$ | 0.56±0.05$^{abc}$ |
| National Product 2 | 0.61±0.41$^{r}$ | 0.62±0.49$^{rs}$ | 0.61±0.41$^{r}$ | 0.61±0.41$^{r}$ |

Effect of storage time on flowability was significant (Means carrying the same letter in row and column are statistically non-significant)

**Table 21. Comparison for bulk density of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 0.52±0.10$^{am}$ | 0.53±0.10$^{ap}$ | 0.54±0.01$^{a}$ | 0.530±0.12$^{p}$ |
| International Product 2 | 0.60±0.17$^{ab}$ | 0.59±0.17$^{abc}$ | 0.58±0.17$^{ba}$ | 0.59±0.71$^{ab}$ |
| Milk fresh | 0.55±0.16$^{mn}$ | 0.55±0.16$^{mno}$ | 0.58±0.61$^{o}$ | 0.56±0.16$^{p}$ |
| National Product 1 | 0.49±0.10$^{ba}$ | 0.46±0.10$^{ba}$ | 0.41±0.01$^{ba}$ | 0.45±0.10$^{ba}$ |
| National Product 2 | 0.61±0.25$^{c}$ | 0.58±0.61$^{ca}$ | 0.56±0.16$^{cm}$ | 0.58±0.61$^{cap}$ |

Effect of storage time on bulk density was significant (Means carrying the same letter in row and column are statistically non-significant)

***Bulk density*****:** Major primary consolidating stress affects powder bulk density, or solid weight per unit volume. The bulk density of nonfat dry milk ranges from 0.18 to 1.25 g ml$^{-1}$. Nonfat dry milk is typically 0.50-0.60 g ml$^{-1}$ when spray-dried, and 0.30-0.50 g ml when roller-dried (Do *et al.*, 2020). A volume in mL of 100g of powder represents bulk density. For functionality, economy, and market requirements, dairy-based powder bulk density is crucial (Brandao *et al.*, 2017). Table 21 demonstrates that the National Product 2 bulk density was 0.61 at 0-day analysis, decreased at 30, 60, and 90 days, and larger in all samples. National Product 1's sample had the lowest value at 0 days and decreased after 30, 60, and 90 days. Table 22 displays noteworthy outcomes. Particle density (occluded air and solids) and interstitial air determine milk powder bulk density (Kim *et al.*, 2003). Density of solids, occluded air, particle density, and interstitial air all affect bulk density. Occluded air is crucial to bulk density regulation (Ding *et al.*, 2021). The bulk density of a powder is its weight divided by its volume, usually in g/ml or kg/l. Bulk densities at 0, 100, 625, and 1250 taps were measured, and Hausner ratio (HR) values indicated powder flowability. No substantial bulk density changes detected between WMP/SMP. Differences in sample bulk density between manufacturers reflect different processing conditions.

**Table 22. Analysis of variance of comparison for bulk density of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 3.03700 | 0.7592 | 6.62* |
| Storage days | 4 | 3.0553 | 0.7638 | 6.66* |
| Samples*days | 16 | 7.04253 | 0.08048 | 5.46$^{NS}$ |
| Error | 35 | 4.011 | 0.1146 | |
| Total | 39 | | | |

*=Significant; NS= Non Significant

***Total solids*****:** Brandao *et al.* (2017) examined how solids concentration, heating, and storage temperatures affect reconstituted whole milk concentrate rheology. A custom recombination rig regenerated the powder at 35 degrees C to 10-48% total solids (TS). Concentrates were heated to 45-85 degrees C and stored there. The yield stress increased from 40% TS to 44% TS, and time-dependent behavior was detected above 44% TS. Newtonian behavior was observed below 30% TS. Storage period decreased flow behavior index but raised yield stress and consistency coefficient with age thickening. During age thickening, milk concentrates strayed from Newtonian behavior (Cattaneo *et al.*, 2013). Table 23 showed that National Product 2 mean value was 18.1 for all samples and 18.0 for 30, 60, and 90 days.

**Table 23. Comparison for total solids of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | 17.10±0.15$^{a}$ | 17.10±0.15$^{a}$ | 16.90±0.14$^{ab}$ | 17.03±0.11$^{bc}$ |
| International Product 2 | 17.33±0.14$^{ap}$ | 17.21±0.14$^{abc}$ | 17.21±0.54$^{ab}$ | 17.20±0.54$^{ba}$ |
| Milk fresh | 17.80±0.02$^{m}$ | 17.80±0.02$^{mn}$ | 17.60±0.22$^{qr}$ | 17.60±0.22$^{s}$ |
| National Product 1 | 16.46±0.11$^{cd}$ | 16.46±0.11$^{c}$ | 16.41±0.12$^{cq}$ | 16.41±0.12$^{ca}$ |
| National Product 2 | 18.10±0.11$^{bc}$ | 18.00±0.10$^{bc}$ | 18.00±0.10$^{bc}$ | 18.00±0.20$^{bc}$ |

Effect of storage time on total solids was highly significant (Means carrying the same letter in row and column are statistically non-significant)

National Product 1 had the lowest mean value in all samples and declined to 16.41 after 60 and 90 days analysis. International Product 2 was 17.33 at 0 days, 17.21 at 30, 60 days, and 17.20 at 90 days. The average International Product 1 value at 0 and 30 days was 17.1. Table 23 shows that it reduced after 60 days and climbed after 90 days, around 17.03. Table no. 24 indicated that the results were highly significant.

**Table 24. Analysis of variance of comparison for total solids of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 0.6827 | 0.1707 | 15.51** |
| Storage days | 4 | 0.8313 | 0.2078 | 18.80** |
| Samples*days | 16 | 2.6000 | 0.1625 | 14.77** |
| Error | 10 | 2.1100 | 0.0110 | |
| Total | 34 | | | |

**= Highly Significant

***Solid not fat***: According to Lloyd *et al.* (2008), solids-not-fat contain protein (casein and lactalbumin), carbs (lactose), and minerals. To make milk powder, Liang *et al.* (2004) removed water from pasteurized skim (nonfat or fat-free) milk. Unless otherwise stated, the product includes no more than 5% moisture and 1.5% milkfat. Table 25 shows that International Product 1 had the highest mean value of 10.70 at zero-day analysis and declined after 90 days. The lowest mean value of all samples was 6.66 for Milk Fresh at 30 days. The International Product 2 mean value at 0 and 30 days was 9.28, but it dropped to 9.18 or 9.16 at 60 and 90 days. National Product 1's mean value was 9.34 at 0 days and fell by 30, 50, and 90 days. National Product 2 mean value was 8.61 at the 0 and 30 days analysis, and 8.60 at 60 and 90 days. Table 26 shows the outcome was significant. Brandao *et al.* (2017) tested milk powder's stability for up to 12 months at room temperature for proteolysis, oxidation, solid not fat, and color. The results showed that oxidation product and solid not fat concentrations reduced, but not more than in commercial powder stored under identical conditions.

**Table 26. Analysis of variance of comparison for solid not fat of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 2.06 | 0.515 | 11.625** |
| Storage days | 4 | 2.007 | 0.5017 | 11.32** |
| Samples*days | 16 | 8.1129 | 0.5070 | 11.45** |
| Error | 25 | 1.1089 | 0.0443 | |
| Total | 34 | | | |

**= Highly Significant

***Microbial analysis***: According to Torres *et al.* (2017), Aspergillus, Bacillus, Enterococcus, Micrococcus, Mucor, Penicillium, Rhizopus, and Streptococcus can deteriorate dried milk powder. Milk and dairy products with high microbial loads deteriorate and cost producers (Di Pinto *et al.*, 2013). Lloyd *et al.* (2008) suggested that microbiological analysis of powdered milk could assess production hygiene and drying efficiency. It will provide shelf life predictions and microorganism detection that may pose health problems.
TPC: Total plate count Total plate count helps identify living bacteria. Total plate count for all samples is shown in Table 27. This table shows that the National Product 2 sample had the greatest mean value at 0 day, 3400, and decreased in 30, 60, and 90 days. The International Product 2 had the lowest mean value of all samples, about 1100, which increased in 30, 60, and 90 days. National Product 1, Milk fresh, and

**Table 25. Comparison for solid not fat of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | $10.52\pm0.10^{a}$ | $10.51\pm0.10^{ab}$ | $10.51\pm0.01^{abc}$ | $10.51\pm0.01^{a}$ |
| International Product 2 | $9.28\pm0.14^{amn}$ | $9.28\pm0.14^{mn}$ | $9.18\pm0.41^{o}$ | $9.16\pm0.41^{op}$ |
| Milk fresh | $6.84\pm0.09^{b}$ | $6.66\pm0.21^{c}$ | $6.68\pm0.31^{bc}$ | $6.72\pm0.11^{abc}$ |
| National Product 1 | $9.34\pm1.21^{ba}$ | $9.15\pm1.31^{a}$ | $9.14\pm1.31^{ab}$ | $9.14\pm1.31^{ba}$ |
| National Product 2 | $8.61\pm0.12^{cd}$ | $8.61\pm0.11^{c}$ | $8.60\pm0.10^{ca}$ | $8.60\pm0.10^{cp}$ |

The effect of storage time on solid not fat was highly significant (Means carrying the same letter in row and column are statistically non-significant)

**Table 27. Comparison for TPC of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | $2150\pm02.09^{am}$ | $2150\pm02.09^{a}$ | $2154\pm02.31^{mn}$ | $2151.3\pm02.31^{op}$ |
| International Product 2 | $1100\pm04.07^{ab}$ | $1100\pm40.07^{ab}$ | $1950\pm480.1^{d}$ | $1383.3\pm471.9^{f}$ |
| Milk fresh | $2900\pm03.46^{e}$ | $2900\pm03.46^{r}$ | $2906\pm03.41^{ep}$ | $2902.0\pm03.45^{e}$ |
| National Product 1 | $2700\pm14.74^{q}$ | $2678\pm14.71^{qr}$ | $2706\pm14.70^{qrs}$ | $2694.6\pm14.74^{qrst}$ |
| National Product 2 | $3400\pm15.27^{0}$ | $3100\pm15.01^{op}$ | $3200\pm147.1^{c}$ | $3233.3\pm151.0^{cd}$ |

The effect of storage time on TPC was significant (Means carrying the same letter in row and column are statistically non-significant)

International Product 1 had mean 0-day values of 2700, 2900, and 2150. Table 28 showed significant results. Heat-processing milk lowers water activity, killing pathogenic and spoilage microorganisms and inactivating enzymes. Heating/drying reduces redox potential and extends the shelf life of dried milk powder at room temperature (Cao *et al.*, 2013). Dried milk powder must be free of Escherichia coli, Listeria monocytogenese, Salmonella, and Shigella, according to Cattaneo *et al*. (2013).

**Table 28. Analysis of variance of comparison for TPC of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 2.9982 | 0.74 | 12.62* |
| Storage days | 4 | 2.018 | 0.5045 | 8.609* |
| Samples*days | 16 | 8.798 | 0.5498 | 9.38* |
| Error | 40 | 4.108 | 0.0586 | |
| Total | 36 | | | |

*= Significant

***Sensory analysis*:** Guaranteed testing relies on sensory assessment. Sensory assessment is essential when evaluating food (Perveen *et al.*, 2015). Skim milk powder should taste and smell light. Long-term storage can cause milk powder to lose flavor. You may see these in rehydrated or "recombined" milk. Milk powders used in manufactured foods and dry blends demand less palatability and dispersibility (Ballom *et al.*, 2020).

***Color*:** Food color affects consumer quality perception. Colored natural ingredients and processed components give foods their color (Boiarkina *et al.*, 2017). Table 29 shows milk powder mean values for all samples. National Product 2 mean value was 9.00 at 0-day analysis and grew at 30, 60, and 90 days.

It was the highest sample value. National Product 1 had the lowest score at 0-day analysis, 7.00. At 0-day analysis, International Product 1, Milk Fresh, and International Product 2 had mean values of 8.00. Table 30 shows that the powdered milk sample color was considerably recorded. Gulati *et al.* (2019) suggested that non-enzymatic browning, Maillard reaction, and powdered milk chemical activity could modify the color. Powdered milk with the least water content changes little. Table 30 showed significant results. Differences across samples and days were insignificant. No color change while storage. Baldwin *et al.* (2020) found that raw material processing at the pilot-scale spray drier altered protein and fat content in the powder, which could have affected quality metrics. The resulting powders had low moisture content.

**Table 30. Analysis of variance of comparison for color of commercially available dried milk powder.**

| Source | DF | SS | MS | F |
|---|---|---|---|---|
| Samples | 4 | 3.8632 | 0.9658 | 8.47* |
| Storage days | 4 | 3.0298 | 0.7574 | 6.64* |
| Samples*days | 16 | 8.8251 | 0.1769 | $3.11^{NS}$ |
| Error | 35 | 4.0120 | 0.1140 | |
| Total | 39 | | | |

*** =** Significant; NS= Non significant

The results of this comparative study reveal notable differences in the safety and quality of commercially available milk powders. While all products tested complied with basic safety regulations, significant variations were found in certain parameters, such as microbial contamination, nutrient composition, and the presence of trace contaminants. Some brands exhibited higher levels of bacterial contamination, which could pose health risks, especially for susceptible groups like infants and the elderly. These variations may be linked to differences in production practices, storage conditions, or the rigor of quality control procedures employed by different manufacturers.

On the nutritional front, discrepancies were observed in the levels of fat, protein, total solids which could affect the product's nutritional value and overall benefit to consumers.

These findings highlight that, while the majority of commercially available milk powders are generally safe, there is a need for more stringent oversight of manufacturing processes and clearer labeling practices, particularly in relation to nutrient content and contaminant testing. Further research is required to assess the long-term health effects of regular consumption of these products and to evaluate the effectiveness of current regulatory frameworks in ensuring consumer safety.

***Conclusion*:** It can be concluded that all the samples of powdered milk accomplished the compositional requirement, despite the fact that the samples of powdered milk assorted from each other on parameters like pH, acidity, moisture, ash,

**Table 29. Comparison for color of commercially available dried milk powder.**

| Samples | 0 day | 30 days | 60 days | 90 days |
|---|---|---|---|---|
| International Product 1 | $8.00\pm0.04^{ac}$ | $8.00\pm0.04^{ac}$ | $7.89\pm0.61^{df}$ | $7.96\pm0.02^{f}$ |
| International Product 2 | $8.00\pm0.11^{ac}$ | $8.00\pm0.12^{ac}$ | $8.21\pm0.11^{ab}$ | $8.07\pm0.11^{ad}$ |
| Milk fresh | $7.00\pm0.12^{pqr}$ | $7.00\pm0.12^{s}$ | $7.21\pm0.01^{r}$ | $7.07\pm0.04^{q}$ |
| National Product 1 | $8.00\pm0.05^{sd}$ | $8.00\pm0.05^{f}$ | $8.01\pm0.01^{p}$ | $8.00\pm0.05^{sd}$ |
| National Product 2 | $9.00\pm0.18^{p}$ | $9.24\pm0.21^{m}$ | $9.24\pm0.11^{cab}$ | $9.16\pm0.11^{c}$ |

The effect of storage time on solid not color was significant (Means carrying the same letter in row and column are statistically non-significant)

fat, protein and bulk density. It was also found that the powdered milk manufactured in our country may be the less shelf life as compared to international brands. Significant changes might be because of two fundamental reactions lipid oxidation and Maillard reaction. Basic cause of inferior quality of milk resulting from low storage stability of powdered milk. It may be due to lower quality raw milk due to poor processing conditions, adulterations, storage conditions beside because of lack of appropriate packaging.

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